

CALIFORNIA DIVISION OF MINES AND GEOLOGY
FAULT EVALUATION REPORT FER-155

Faults in Bridgeport Valley and Western Mono Basin, Mono County

by

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INTRODUCTION

Potentially active faults located in central Mono County in the Bridgeport Valley include the Robinson Creek fault, Bridgeport Valley fault zone (with associated faults in Bridgeport Valley), and the Hunewill Hills fault zone (figure 1). A major north- and northwest-trending fault borders the west side of Mono Lake and is termed the Mono Lake fault (figure 1). The study area is located in portions of the Fales Hot Springs, Bridgeport, Matterhorn Peak, Bodie, and Mono Craters 15-minute quadrangles. These faults are evaluated as part of a statewide effort to evaluate faults for recency of movement. Those faults determined to be sufficiently active and well defined are zoned by the State Geologist as directed by the Alquist-Priolo Special Studies Zones Act (Hart, 1980).

SUMMARY OF AVAILABLE DATA

The Bridgeport Valley/Mono Basin study area is characterized in general by Basin and Range style normal faulting. However, warping with associated faulting has produced the topographically low areas of Bridgeport Valley and Mono Basin and the intervening topographic high of the Bodie Hills (Al-Rawi, 1969; Gilbert, et al., 1968; Sharp, 1972; Envicom, 1976; Higgins, et al., 1983). Thus, Bridgeport Valley and Mono Basin are not considered to be grabens or calderas.

Topography in the study area is varied. Bridgeport Valley is a relatively flat, northeast-sloping meadowland surrounded on all sides by hills and mountains of gentle to relatively rugged relief. Mono Basin is a gently southwest-sloping structural depression that is abruptly truncated on the west by mountains of rugged relief and on the north by mountains of relatively rugged relief.

Predominant rock types in the Bridgeport Valley study area include Cretaceous granitic rocks in the mountains to the southwest and extensive Mio-Pliocene volcanic rocks in the mountains along the western, northwestern, and eastern margins of Bridgeport Valley (Koenig, 1963; Chesterman, 1975; Dohrenwend and Brem, 1982). Abundant Pleistocene glacial deposits (Tahoe and Tioga stage) occur in Robinson and Buckeye Creeks, and till of probable Sherwin age (> 700,000 yrs. BP) occurs along most of the southern margin of Bridgeport Valley (Dohrenwend, 1982a). Sharp (1972) postulates that coarse glacial outwash deposits underlie the Bridgeport Valley and may correlate with gravels exposed in the foothills along the northeast side of Bridgeport Valley (see Dohrenwend and Brem, 1982). Tioga stage glacial outwash and latest Pleistocene to Holocene alluvium occur throughout most of Bridgeport Valley (Clark, et al., 1983; Dohrenwend, 1982a).

Predominant rock types in the Mono Basin study area include Cretaceous granitic rocks with associated Paleozoic roof pendant rocks along the west margin of the basin, Sherwin till underlain by Cretaceous granitic rocks, and Mio-Pliocene volcanic rocks to the north, extensive volcanic rock of Pleistocene and Holocene age to the south, and latest Pleistocene to Holocene lake deposits to the east (Chesterman and Gray, 1975; Kistler, 1966; Dohrenwend, 1982a; Koenig, 1963; Stewart, et al., 1982).

Development in the Bridgeport Valley/Mono Basin study area is minimal. With the exception of the towns of Bridgeport and Lee Vining, and the agricultural use in Bridgeport Valley (mainly cattle grazing), land surfaces have not been significantly modified by man.

BRIDGEPORT VALLEY AREA

Several north- to northwest-trending normal faults, generally with down-to-the-east displacement, have been mapped in the Bridgeport Valley area (figure 1). In this FER, these faults will be termed the Robinson Creek fault, Bridgeport Valley fault zone (including the western, central, eastern, and southern segments), and the Hunewill Hills fault zone (figures 1, 2). Additional associated faults are included on figure 2. Existing maps evaluated in this FER include Chesterman (1975), Envicom (1976), Dohrenwend (1982a, 1982b), and Dohrenwend and Brem (1982) (figure 2). Mapping by Halsey (1953) is too generalized for evaluation in this FER.

Bridgeport Valley Fault Zone

The Bridgeport Valley fault zone (BVF) mapped by Dohrenwend (1982a, 1982b) and Dohrenwend and Brem (1982) consists of western, central, eastern, and southern segments (figures 1, 2). These faults trend north and have down-to-the-east normal displacement. With the exception of the southern segment, all faults offset alluvium of latest Pleistocene to Holocene age as classified by Dohrenwend (1982a) (figure 2). The southern segment offsets Pleistocene outwash gravels (Dohrenwend's Qog unit), but does not offset late Pleistocene to Holocene alluvium (figure 2). Envicom (1976) maps a queried, north-trending fault that generally corresponds to the western BVF, although Envicom's fault extends farther to the south.

Chesterman (1975) did not map the western BVF.

Robinson Creek Fault

The Robinson Creek fault is located along the northwest side of Bridgeport Valley (figures 1, 2). This north- to northeast-trending fault is characterized by down-to-the-east displacement. Dohrenwend (1982b) considered the Robinson Creek fault to be a major range front fault. Chesterman (1975) mapped the fault as concealed by Tahoe, Tenaya, and Tioga glacial deposits in Robinson Creek (figure 2). Envicom (1976) mapped an approximately located fault along the west side of Bridgeport Valley from Sec. 16, T4N, R24E north to Boone Canyon (figure 2). Tahoe glacial deposits are offset along the fault, but just north of Bogards Camp, glacial deposits considered to be of Tenaya age (~ 50,000 yrs. BP) are not offset (Envicom, 1976) (figure 2). Holocene alluvium in Swauger Creek is not offset, and to the north of this creek, two subparallel traces offset Mio-Pliocene volcanic rocks (Koenig, 1963; Envicom, 1976; Stewart, et al., 1982) (figure 2).

Discontinuous benches and saddles delineate the fault traces mapped by Envicom (1976) north of Swauger Creek (figure 2). Remnants of late Tertiary to Pleistocene alluvial gravels crop out on these benches and saddles and may correlate with the alluvial gravels that occur in the hills along the east side of Bridgeport Valley (Sharp, 1972; Dohrenwend and Brem, 1982). These uplifted gravels indicate that a fault is located along the base of the slope.

Dohrenwend (1982a) mapped the Robinson Creek fault from just south of Bogards Camp to By-Day Creek (figure 2). Dohrenwend mapped late Pleistocene to Holocene alluvium offset against Tahoe glacial deposits between Bogards Camp and Buckeye Creek. Mesozoic granitic and Miocene volcanic rocks mapped by Stewart, et al. (1982) are offset north of Buckeye Creek. Dohrenwend (1982a) considered the Robinson Creek fault to be well defined along Robinson Creek, but less well defined north of Buckeye Creek (figure 2). The location of fault traces mapped by Envicom (1976) and Dohrenwend (1982a) agree reasonably well south of Buckeye Creek, but considerable variation is apparent in the area in and just north of Buckeye Creek (figure 2).

Dohrenwend (1982a) did not observe evidence of Quaternary faulting northeast of By-Day Creek (figure 2). However, Dohrenwend (1982b) extended the Robinson Creek fault northeast to near Boone Canyon (figure 2). It is not entirely clear to this writer why this contradiction exists. The 1982a map of Dohrenwend shows only those faults that directly can be shown to offset Quaternary deposits or that have geomorphic evidence that can be inferred to indicate Quaternary faulting. Several large landslides were mapped by Dohrenwend (1982a) along the west side of Bridgeport Valley north of Swauger Creek. Perhaps in Dohrenwend's 1982b map, major late Quaternary faulting is inferred, but direct evidence is obscured by landslides.

Hunewill Hills Fault

Northwest-trending faults have been mapped by several workers along the north side of the Hunewill Hills (Chesterman, 1975; Envicom, 1976; Dohrenwend, 1982a, 1982b) and along the south side of the Hunewill Hills by Dohrenwend (1982) (figure 2). Sharp (1972) postulated that the Hunewill Hills have been downfaulted following Sherwin () glaciation, based on the lack of evidence that the hills at some time were buried by ice. Higgins, et al. (1983) postulate that an inferred northwest-trending fault along the south side of the Hunewill Hills may be structurally related to the Robinson Creek fault to the northwest and the Mono Lake fault to the southeast (figure 4).

Chesterman (1975) mapped a northwest-trending fault with down-to-the-northeast displacement along the north flank of the Hunewill Hills (figure 2). The fault offsets Miocene volcanic rocks, but Holocene alluvium to the northwest and Sherwin glacial deposits (> 700,000 yrs. BP) to the southeast are not shown to be offset (Chesterman, 1975) (figure 2). Dohrenwend (1982a, 1982b) mapped a fault similar to Chesterman's trace, but Dohrenwend did not observe evidence of offset Quaternary deposits or geomorphic expression of Quaternary faulting (figure 2). Envicom (1976) mapped a northwest-trending fault that splays into three traces to the southeast (figure 2). Alluvium is faulted against Miocene volcanic rocks along the base of the hills, but the fault does extend into the alluvium northwest of Hunewill Hills (figure 2).

Four subparallel, northwest-trending faults offset a Tahoe lateral moraine and extend into alluvium north of Hunewill Hills (Envicom, 1976) (figure 2). These faults are approximately located and exhibit a curious structural relationship with the western BVF (figure 2). Two faults are truncated by the western BVF, and two segments cross the western BVF with no apparent offset of either fault zone (figure 2). Northwest of the eastern

Robinson Creek lateral moraine in Sec. 11, the northwest-trending faults do not offset late Pleistocene to Holocene alluvium, except for a short segment in the NE-1/4 Sec. 10, T4N, R24E (figure 2). Envicom (1976) postulated a concealed connection between these northwest-trending faults and the Robinson Creek fault (figure 2).

The northwest-trending fault along the south side of Hunewill Hills offsets Pleistocene glacial deposits (probably Sherwin age) and Miocene volcanic rocks, but Holocene alluvium is not offset (Dohrenwend, 1982a; Stewart, et al., 1982) (figure 2). The fault as mapped by Dohrenwend does not extend far enough to the southeast where a Tahoe stage lateral moraine is located (Sect. 8, T3N, R25E) (figure 2).

Bridgeport Reservoir Fault Zone

Short, northeast-trending normal faults have been mapped at the northern end of Bridgeport Valley along both the east and west sides of Bridgeport Reservoir (figure 2). The western Bridgeport Reservoir fault zone consists of two parallel, relatively short fault segments that offset late Pleistocene and Holocene alluvium (figure 2). These faults have been mapped by Envicom (1976), Dohrenwend (1982a, 1982b), Dohrenwend and Brem (1982), and Higgins, et al. (1983) (figure 2). With the exception of Envicom (1976), the location of fault traces mapped by these workers agree fairly well.

A north-trending fault along the east side of Bridgeport Reservoir, mapped by Dohrenwend and Brem (1982), offsets late Tertiary to Quaternary gravels against Mio-Pliocene volcanic rocks (figure 2). Late Pleistocene to Holocene alluvium is not offset by this fault zone, except for a very short segment in Section 9, T5N, R25E (figure 2). Dohrenwend (1982a) did not observe evidence of faulted late Pleistocene to Holocene alluvium.

Faults A, B, and C

Short, north-northeast-trending faults mapped by Dohrenwend (1982a) and Chesterman and Gray (1975) are delineated as faults A, B, and C (figure 2). Faults A and B are mapped as offsetting late Pleistocene to Holocene alluvium by Dohrenwend (1982a) (figure 2). Chesterman and Gray (1975) mapped two parallel faults that almost coincide with Dohrenwend's trace of fault A. However, Chesterman and Gray do not map late Quaternary alluvium offset along this fault (figure 2). Fault C offsets older glacial deposits (probably equivalent to Sherwin age) mapped by Dohrenwend (1982a), but late Pleistocene to Holocene alluvium is not offset (figure 2).

MONO BASIN AREA

Mono Lake Fault Zone

A major, north- to northwest-trending normal fault (Mono Lake fault zone) forms the western margin of the Mono Basin (figure 1). Gilbert, et al. (1968) postulate that as much as 6,000 feet of down-to-the-east, vertical displacement has occurred along the Mono Lake fault zone. They contend that the 3,000-foot escarpment west of Mono Lake developed after older glacial deposits (Sherwin (?)) were deposited at Conway Summit, and that another 3,000 feet of displacement is buried beneath sediments of Mono Lake.

Traces of the Mono Lake fault zone have been mapped by Kistler (1966), Chesterman and Gray (1975), Envicom (1976), and Dohrenwend (1982a, 1982b) (figure 2). Dohrenwend (1982b) classified the Mono Lake fault zone as a major range-front fault. Chesterman and Gray (1975) mapped a north-trending fault from around Lundy Canyon north to Conway Summit. Tahoe lateral moraines are offset along this fault within and south of Lundy Canyon (figure 2). North of Lundy Canyon, Chesterman and Gray mapped Paleozoic and Mesozoic roof pendant rocks as offset along two subparallel traces of the Mono Lake fault (figure 2). However, Holocene talus and alluvium are not offset where the deposits cross the eastern fault trace (figure 2). Near Conway Summit, the Mono Lake fault is concealed by glacial deposits of Sherwin age. Generally, all workers map the Mono Lake fault zone as concealed by late Pleistocene to Holocene lake deposits from Dechambeau Creek to about two miles south of Lee Vining (Dohrenwend, 1982; Chesterman and Gray, 1975; Kistler, 1966; Envicom, 1976) (figure 2). However, a very short fault segment in the center of Sec. 24, T2N, R25E reportedly offsets post-Tioga lake deposits (Chesterman and Gray, 1975) (figure 2).

The Mono Lake fault mapped by Dohrenwend (1982a) offsets Tahoe glacial deposits in Lundy Canyon, although the location of the fault is shown to lie farther east than the fault mapped by Chesterman and Gray (1975) (figure 2). Late Pleistocene to Holocene talus and alluvium are offset along the trend of the Mono Lake fault (Dohrenwend, 1982) (figure 2). Dohrenwend, like Chesterman and Gray (1975), mapped the north end of the fault as concealed by Sherwin glacial deposits just south of Conway Summit (figure 2).

Envicom (1976) mapped the Mono Lake fault as offsetting Tahoe glacial deposits in Lundy Canyon and as concealed by lake deposits south of Dechambeau Creek (figure 2). The location of the fault is close to that of Dohrenwend (1982), but to the south, there is no consensus between various workers regarding the location of recently active traces of the Mono Lake fault. A short northwest-trending fault was mapped south of Lee Vining Creek and is considered to be the southern segment of the Mono Lake fault zone (Envicom, 1976) (figure 2). An abrupt lithologic change in Tahoe moraine deposits was interpreted by Envicom as evidence of faulting (figure 2). However, Envicom concluded that the Mono Lake fault zone is not Holocene active, based on the lack of evidence of post-Tioga displacement.

Clark et al. (1983) consider the Mono Lake fault zone to vertically offset a Tioga recessional moraine (10,000-15,000 yrs. BP) in Lundy Canyon by about 23 meters (figure 2). They calculated a late Quaternary slip rate of 2.5mm/yr. for this segment of the fault zone. Gilbert, et al. (1968) assumed a maximum Quaternary slip rate of about 1.2mm/yr. for the fault segment just west of Mono Lake..

INTERPRETATION OF AERIAL PHOTOGRAPHS AND FIELD OBSERVATIONS

Air photo interpretation by this writer of faults in the Bridgeport Valley study area was accomplished using U.S. Bureau of Land Management air photos (CA01-77, 1977, 1:24,000 scale) and U.S. Department of Agriculture air photos (CNL, 1940, 1:20,000 scale). Air photo interpretation of the Mono Basin study area was accomplished using U.S. Forest Service air photos (IN04, 1977, 1:15,840 scale; EME, 1963, 1:15,840 scale) and U.S. Department of Agriculture air photos (CNL, 1940, 1:20,000 scale).

Approximately two days were spent in the Bridgeport/Mono Basin study area in August 1983 by this writer in order to verify selected fault segments interpreted from air photos. In addition, subtle features not observable on the air photos were mapped in the field. An additional 1/4 day in September 1983 was spent with E. Hart in the Lee Vining area, and 1/4 day in February 1984 was spent by this writer about three miles north of Lee Vining. Results of air photo interpretation and field observations by this writer are summarized on figure 3.

Significant observations based on both air photo interpretation and field observations by this writer, and mapping by others, are summarized in Table 1. Locality numbers identified on figures 2 and 3 refer to specific data relative to fault recency, degree of definition (i.e. well-defined or poorly defined), ages of deposits that are offset or that conceal faults, and additional pertinent information. Table 1, in conjunction with figures 2 and 3, contains the majority of supporting data relevant to zoning decisions.

An attempt was made to measure fault scarp profiles in order to estimate recency of faulting based on the work of Wallace (1977). Points of observation and locations where fault scarp profiles were measured are shown on figure 3 and are summarized in Table 2. It should be emphasized that these measurements represent only approximations of scarp height, scarp-slope angle, and width of scarp crest. Scarp height was measured using the method described by Lahee (1961, p. 454). Scarp-slope angle was estimated by using a Brunton compass clinometer and an improvised leveling rod, as described by Wallace (1977). The width of the scarp's crest was estimated by pacing.

A direct correlation between the ages indicated by fault scarp profiles measured by Wallace (1977) in Nevada and scarp profiles measured during investigations for this FER cannot be made due to different lithology, climate, and styles of faulting (Mayer, 1982). However, the data presented by Wallace (1977, 1978) can be used as a guide (or additional factor) when evaluating the geomorphic features and age of offset deposits (when known) for recency of faulting. Some very general guidelines for estimating scarp ages are summarized as follows: scarp-slope angles for faults in unconsolidated alluvium and colluvium no older than 10,000 to 12,000 yrs. BP can range from 10° to 35° (Wallace, 1977). The average scarp angle is about 22° based on figure 8 of Wallace (1977), although figure 12 of Wallace (1977) indicates that scarp angles of about 19° represent minimum Holocene age. The scarp crest width for scarps no older than about 10,000 yrs. BP range from 3.2 to about 19 feet (figure 11 from Wallace, 1977). Wide variations occur, but these figures probably represent minimum (i.e. conservative) criteria suggesting Holocene ages. The Bridgeport/Mono Basin study area is generally wetter than Wallace's Nevada study region and is probably subject to more rapid degradation of the geomorphic features.

BRIDGEPORT VALLEY AREA

Bridgeport Valley Fault Zone

North- to northeast-trending faults in Bridgeport Valley are generally very well defined by scarps and associated tonal lineaments (figure 3). It is conceivable that these features could have been formed by lateral erosion of north- to northeast-flowing streams some time in the past. However, surfaces bounded by these generally east-facing scarps are offset. The upthrown blocks also seem to be tilted (generally toward the west), suggesting that these faults define a zone of extension in association with downwarping and faulting

along the west side of Bridgeport Valley. Ephemeral geomorphic features observed at localities 4 through 7 and 9, strongly indicate a fault origin rather than erosional origin. Scarp profiles measured at localities 4 and 7 are not very steep (120° to 150° and $\sim 100^{\circ}$, respectively) and could be interpreted as suggesting lack of offset during the Holocene. However, precipitation is relatively high in the Bridgeport area (compared to Nevada where Wallace's data originated), the meadowland (which consists of soft, unconsolidated, relatively fine-grained alluvium) is usually saturated (standing water on upthrown fault blocks observed in August 1983), and most of the valley is utilized for cattle grazing. Thus, scarp degradation occurs at a relatively rapid rate, and low scarp angles probably are not inconsistent with Holocene activity.

Fault segments mapped by Dohrenwend (1982a) and Dohrenwend and Brem (1982) generally agree with the faults mapped by this writer (figures 2, 3). Differences in detail exist, but these differences probably are related to the small-scale base map used by Dohrenwend (1982a).

A slip rate along the western Bridgeport Valley fault zone is estimated to be about 0.2 mm/yr, assuming that the alluvium is equivalent to late Tioga outwash. This rate probably represents a minimum because vertical displacement seems to be distributed across Bridgeport Valley.

Robinson Creek Fault Zone

The Robinson Creek fault zone defines the western margin of Bridgeport Valley. The north-trending, east-facing scarp along the west side of Robinson Creek is generally well defined. However, there is doubt among some geologists as to the origin of this east-facing scarp and its relationship to glacial deposits in Buckeye Creek. Sharp (1972) suggests that the 70- to 100-foot high scarp in Tahoe deposits could be a glacial feature formed as a result of the intersection of the Robinson Creek and Buckeye Creek glaciers. South of Buckeye Creek, the fault trend is parallel to Robinson Creek, and the scarp conceivably could be formed entirely by glacial action. However, Clark, et al. (1983) contend that a 13-foot-high scarp in late Tioga outwash is fault related (figure 3, Table 2). Clark, et al. (1983) calculated a slip rate for this fault (which they call the Bridgeport Basin fault) of between 0.2 to 0.7 mm/yr (preferred rate 0.5 mm/yr). A scarp profile measured in Tahoe glacial deposits just south of locality 2 by this writer (figure 3) yields an estimated slip rate of about 0.6 mm/yr if the displacement occurred within the last 60,000 years and 0.3 mm/yr if the displacement occurred within the last 130,000 years. This estimated slip rate seems compatible with the slip rate calculated by Clark, et al. (1983) and suggests that systematic displacement has occurred along the Robinson Creek fault. A truncated alluvial fan, vertically offset drainages, and linear vegetation contrasts are all associated with a well-defined, east-facing scarp, strongly indicating Holocene faulting (localities 1 and 2, figure 3, Table 1).

The Robinson Creek fault zone is not as well defined north of Buckeye Creek. Tahoe glacial deposits are truncated just north of the creek, but it is difficult to follow the fault north into Mio-Pliocene volcanic rocks (figure 3).

The relatively linear hillfront north of Swauger Creek, triangular facets, and incised drainages indicate the location of a fault at the base of the slope (figure 3). A short, east-facing scarp in the alluvium of Swauger Creek is associated with additional linear tonal contrasts in Holocene alluvium (locality 3, figure 3). These features align with the linear hill front to the north and suggest that Holocene faulting discontin-

uously extends along most of the west side of Bridgeport Valley. Landslides obscure geomorphic evidence of faulting northeast of Section 13, T5N, R24E (figures 2, 3).

Hunewill Hills Fault Zone

Several northwest-trending faults were mapped by Envicom (1976) as offsetting alluvium and Tahoe glacial deposits along and near the north side of the Hunewill Hills (figure 2). However, geomorphic evidence of recent faulting was not verified by this writer except where indicated on figure 3. There is a linear escarpment along the north side of the Hunewill Hills, but evidence of Holocene activity is lacking. The large closed depression about 1,500 feet southwest of Summer VABM does not seem to be fault related (figure 3). Scarps were not observed by this writer in the Tahoe lateral moraine that is crossed by several of Envicom's fault traces (figures 2, 3), except for a poorly defined, northeast-facing break in slope, with associated tonal lineaments (figure 3). Holocene alluvium does not seem to be offset southeast of the lateral moraine, but there is a discontinuous tonal lineament and subtle, SW-facing scarp in alluvium northwest of the lateral moraine that may be associated with the poorly defined scarp (figure 3).

The northwest-trending fault along the south side of the Hunewill Hills mapped by Dohrenwend (1982a) was partly verified by this writer (figures 2, 3). A NE-facing scarp in Holocene alluvium may be a stream-cut terrace, but the scarp in alluvium aligns with offset Sherwin-stage glacial deposits to the southeast and offset Tertiary volcanic rocks to the north (locality 13, figure 3). Well-defined north and northwest-trending scarps in Tertiary volcanic rocks north of Summers Creek are associated with closed depressions and may be a southern continuation of the Bridgeport Valley fault zone (figure 3).

Bridgeport Reservoir Fault Zone

Northeast-trending faults along the west side of Bridgeport Reservoir are well defined and are characterized by geomorphic evidence indicating Holocene activity (figures 2, 3; locality 8, Table 1). Fault traces mapped by Dohrenwend and Brem (1982) and this writer agree reasonably well, but the fault traces of Envicom (1976) cannot be verified (figure 2).

Dohrenwend and Brem (1982) mapped late Pleistocene to Holocene alluvium offset along a short segment of the Bridgeport Reservoir fault zone east of the Bridgeport Reservoir (figure 2). The offset in alluvium could not be verified by this writer (figure 2). The eastern Bridgeport Reservoir fault zone, which offsets late Tertiary to Pleistocene alluvium, is delineated by geomorphic features characteristic of erosion along a fault, rather than recent faulting (locality 11, figure 2, Table 1).

Faults A, B, and C

Geomorphic features of Holocene faulting along faults A, B, and C were not observed by this writer, based on air photo interpretation (figure 2). Fault traces mapped by Dohrenwend (1982a) were only locally verified by this writer along faults A and B. Fault C is partly delineated by tonal lineaments in early to middle Pleistocene glacial deposits, but evidence of Holocene faulting was not observed (figure 2).

MONO BASIN AREA

Mono Lake Fault Zone

The Mono Lake fault zone is generally well defined from Dechambeau Creek north to about 1-1/2 miles south of Conway Summit (figure 3, localities 14-17). The fault offsets Tahoe lateral moraines in Lundy Canyon with down-to-the-east displacement (figures 2, 3). Mapping by this writer indicates that, in addition to the Tahoe lateral moraines, the Mono Lake fault zone offsets at least two recessional moraines and outwash deposits of probable Tioga age (locality 17, figure 3). The magnitude of vertical offset decreases both to the north and south of Lundy Canyon. The Mono Lake fault zone is moderately well defined along most of its trend to the north and is characterized by geomorphic evidence of Holocene normal faulting, such as offset alluvial fans and talus cones (locality 14, figure 3). A possible fault exposure (N10°E to N10°W, 68°-70°E) was observed in Paleozoic marble just north of Lundy Canyon (locality 15, figure 3).

The location of recently active traces of the Mono Lake fault zone is problematical south of Dechambeau Creek (figure 3). The trend of the shoreline along most of the west side of Mono Lake is controlled by major down-to-the-east faulting, but late Pleistocene to Holocene geomorphic shoreline features (terraces bounded by east-facing scarps) obscure or mimic geomorphic features produced by faulting. Consequently, most workers have mapped this segment of the Mono Lake fault zone as concealed. However, there may be three locations south of Dechambeau Creek where evidence of Holocene faulting was observed by this writer (localities 18, 19, 20; figure 3; Table 1). Wave-cut terraces are offset vertically at locality 18, and at locality 19, a "wine glass" shaped drainage, associated with a triangular facet and linear vegetation contrasts, indicates recent faulting (figure 3). South of Lee Vining Creek, an east-facing scarp may delineate the southern extent of the Mono Lake fault zone. A stream terrace of probable Holocene age is offset vertically (locality 20, figure 3). South of Tioga Pass road, a wave-cut terrace is vertically offset along the trend of the Mono Lake fault zone. This writer could not verify the "abrupt lithologic change" in the Tioga Pass roadcut observed by Envicom (1976). A complex relationship between Tahoe and/or Tioga glacial outwash deposits, lake, deltaic, and stream deposits exists, but clear evidence of faulting was not observed. Envicom (1976) mapped an approximately located fault that in general agrees with the fault in Lee Vining Creek mapped by this writer, although differences in detail exist (figures 2, 3).

SEISMICITY

Seismicity in the study area is depicted in figure 5. The Mono Lake fault zone is relatively quiescent, although until very recently seismic monitoring in this region has not been adequate. Seismicity in the Bridgeport Basin is somewhat more informative (figure 5). The epicenter quality (A-D) is not sufficient to associate seismicity with individual faults. However, the Bridgeport Valley area is seismically active, especially with respect to seismicity that is apparently concentrated along the valley margins. Seismicity east of Bridgeport Reservoir may be associated with east-dipping faults along the western margins of the valley, or perhaps they are associated with flexure and faulting that may be occurring in the Bodie Hills. Epicenters along the Hunewill Hills may suggest activity along the Hunewill Hills fault zone, although activity along the Bridgeport Valley fault zone also could be indicated.

CONCLUSIONS

Bridgeport Valley Fault Zone

The Bridgeport Valley fault zone consists of north- to northeast-trending normal faults with generally down-to-the-east displacement (figures 2, 3). Dohrenwend (1982a) and Dohrenwend and Brem (1982) mapped the western, central, eastern, and southern segments of the Bridgeport Valley fault zone that were verified by this writer (figures 2, 3). With the exception of the southern segment, all segments of the Bridgeport Valley fault zone offset latest Pleistocene to Holocene alluvium and are characterized by well defined geomorphic features indicating Holocene faulting (figure 3, Table 1). It can be argued that these generally east-facing scarps in alluvium have been formed by stream erosion, but the westward tilt of the upthrown blocks, closed depressions, and a beheaded drainage support a faulting origin (figure 3). The southern segment of the Bridgeport Valley fault zone occurs in Pleistocene older alluvium and does not offset late Pleistocene to Holocene alluvium (locality 9; figures 2, 3; Table 1). However, it is well defined, delineates an offset surface and seems to be associated with other Holocene-active segments of the Bridgeport Valley fault zone.

Robinson Creek Fault Zone

The Robinson Creek fault zone delineates the western margin of Bridgeport Valley and is characterized by down-to-the-east normal faulting (figures 2, 3). Clark, et al. (1983) estimate a slip rate of about 0.5 mm/yr, based on offset late Tloga outwash deposits. Offset Tahoe glacial deposits yield a compatible slip rate of about 0.3 mm/yr to 0.6 mm/yr, based on mapping by Bryant (this report). The Robinson Creek fault is generally well defined and characterized by geomorphic features indicating Holocene activity south of Buckeye Creek (figures 2, 3; Table 1). North of Buckeye Creek, the Robinson Creek fault zone is less well defined (figures 2, 3). Recent faulting is suggested in and just north of Swauger Creek (locality 3; figure 3), but north of By-Day Creek the fault is generally hard to follow (figures 2, 3). The parallel fault traces mapped by Envicom (1976) are not well defined and are generally not characterized by geomorphic features indicating Holocene activity.

Hunewill Hills Fault Zone

The Hunewill Hills are thought to have been downfaulted along an inferred northwest-trending fault (Sharp, 1972; Higgins, et al., 1983) (figure 4). Envicom (1976) mapped several northwest-trending faults along the north side of the Hunewill Hills, but they are generally not well defined and could not be verified by this writer (figures 2, 3; Table 1). A Tahoe lateral moraine is crossed by several of these faults, but no evidence of offset was observed by this writer, with the exception of one poorly defined scarp (locality 10; figure 3). This scarp aligns with a moderately well-defined SW-facing scarp and tonal lineament in late Pleistocene to Holocene alluvium, but well-defined geomorphic features in late Pleistocene to Holocene alluvium were not observed by this writer to the southeast. Sherwin glacial deposits (> 700,000 yrs BP) are offset (down to the east) along the southern Hunewill Hills as mapped by Dohrenwend (1982a) (locality 13; figures 2, 3). A well-defined NE-facing scarp in Holocene alluvium in Summers Meadow aligns with offset Sherwin deposits and suggests Holocene faulting (locality 13; figure 3). North and

northwest-trending, east-facing scarps located north of Summer Creek offset Miocene volcanic rocks and are associated with closed depressions which suggest Holocene faulting (figure 3).

Bridgeport Reservoir Fault Zone

Two short, parallel fault segments offset Pleistocene older alluvium and alluvial fan deposits of late Pleistocene to Holocene age west of Bridgeport Reservoir (figures 2, 3). These fault segments are well defined. The Bridgeport Reservoir fault zone east of Bridgeport Reservoir does not offset late Pleistocene to Holocene alluvium and is delineated by geomorphic features characteristic of erosion along a fault zone rather than recent activity (figures 2, 3).

Mono Lake Fault Zone

The Mono Lake fault zone is generally well defined north of Dechambeau Creek. Tioga recessional moraines are offset in Lundy Canyon and yield a slip rate of 2.5 mm/yr (Clark, et al., 1983) (figure 3). North of Lundy Canyon, the fault zone is characterized by geomorphic evidence indicating Holocene faulting (figures 2, 3; Table 1). South of Dechambeau Creek, the Mono Lake fault zone merges with and is obscured by shoreline features of Mono Lake. All previous workers have mapped the fault as concealed along the west side of Mono Lake (figure 2). However, mapping by Bryant (this report) suggests that Holocene () lake terraces are offset at locality 18 (figure 3). Additional geomorphic evidence at localities 19 and 20 suggest that the Mono Lake fault zone, though generally obscured by old Mono Lake shorelines, exists as a recently active fault as far south as Lee Vining Creek, where Holocene terrace deposits are offset (locality 20; figure 3).

RECOMMENDATIONS

Recommendations for zoning faults for special studies are based on the criteria of "sufficiently active" and "well defined" (Hart, 1980).

Bridgeport Valley Fault Zone

Zone for special studies well-defined traces of the western, central, eastern, and southern Bridgeport Valley fault zone shown on figure 6. Principal references cited should be Dohrenwend and Brem (1982) and this FER.

Robinson Creek Fault Zone

Zone for special studies well-defined traces of the Robinson Creek fault zone shown on figure 6. Principal references cited should be this FER.

Hunewill Hills Fault Zone

Zone for special studies well-defined traces of the Hunewill Hills fault zone shown on figure 6. Principal references cited should be this FER.

Bridgeport Reservoir Fault Zone

Zone for special studies well-defined traces of the western Bridgeport Reservoir fault zone shown on figure 6. Do not zone the eastern Bridgeport Reservoir fault zone. Principal references cited should be Dohrenwend and Brem (1982) and this FER.

Mono Lake Fault Zone

Zone for special studies well-defined traces of the Mono Lake fault zone (including concealed traces) shown on figure 6. Principal references cited should be Envicom (1976), and this FER.

*I have reviewed and generally concur with the recommendations, see pencil notations on fig 6 for minor changes in going (need to check photos in this area).
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3/28/84*

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TABLE 1 (to FER-155). Locality descriptions listing selected data pertinent to fault recency, based on air photo interpretation and field observations by Bryant (this report). Additional data pertinent to fault recency are based on the work of others.

Locality #	Fault Name	Geomorphic feature delineating fault ¹	Fault well defined?	Youngest unit offset & source	Oldest unit not offset & source	Remarks ¹
BRIDGEPORT VALLEY AREA						
1(fig 3)	Robinson Crk. flt. zone	scarp; dov	Yes	late Pleistocene Holocene alluvium (Bryant, this report)	N/A	Well-defined, E-facing scarp truncates Holocene(?) alluvial fan. Scarp profile $h=250$, $\alpha > 20^\circ$, $c \approx 4'-5'$. About 1000' north of this location drainage vertically offset about 3', down to the east, along same scarp.
2(fig 3)	Robinson Crk. flt. zone	scarp	Yes	Late Tioga outwash (Clark, <u>et al.</u> 1983)	N/A	Scarp in late Tioga outwash on S. side of Buckeye Crk. - irrigation canals constructed along toe of scarp to S & N of this location; thus continuity of scarp obscured. Scarp profile: $h=13'$, $\alpha = 22^\circ$, $c \approx 6'$. Steepness of slope angle and lack of soil development and boulder weathering in outwash deposits indicate Holocene faulting.

^{1/} Unless otherwise noted, all observations by Bryant (this report), based on air photo interpretation and field checking. Field observations indicated on figure 3. Refer to figure 3 for symbol explanations.

Table 1 (to FER-155)
Tabulation of Observations

Locality #	Fault Name	Geomorphic feature delineating fault ¹	Fault well defined?	Youngest unit offset & source	Oldest unit not offset & source	Remarks ¹
3(fig,3) ²	Robinson Crk. flt. zone	scarp; t	partly	Holocene alluvium (Bryant, this report); Dohrenwend, 1982a)	N/A	Moderately well-defined east-facing scarp in alluvium of Swauger Crk. Scarp partly modified by construction of Bridgeport Ranger station. Associated tonal lineaments in Holocene alluvium of Swauger Crk. indicate continuation of recent faulting north of Swauger Crk. along linear hillfront. The linear hillfront, triangular facets, and incised drainages indicate faulting at base of slope. A small alluvial fan of probable Holocene age about 2500 feet north of Swauger Crk. seems to be truncated, but additional alluvial fans are not offset. Fault locations of Envicom(1976) are suggested by discontinuous benches, saddles, and linear troughs, but these are probably erosional. In addition, landslides obscure traces of Robinson Crk. fault northeast from Sec. 18, T5N, R25E.

Table 1 (to FER-155)
Tabulation of Observations

Locality #	Fault Name	Geomorphic feature delineating fault ¹	Fault well defined?	Youngest unit offset & source	Oldest unit not offset & source	Remarks ¹
4(fig 3)	W. Bridgeport Valley fault zone	scarp in alluvium; cd	Yes	latest Pleistocene to Holocene alluvium (Dohrenwend, 1982a) late Tioga outwash (Bryant, this report)	N/A	Flt. zone at this locality delineated by well-defined graben. Closed depression located along eastern boundary of graben; scarp profile on W. limb of graben: h=8', $\alpha \approx 120-150^\circ$, c $\approx 4'-5'$. Alluvium is generally fine-grained, relatively soft, and is wet most of the year. Thus, scarp-slope angle probably indicates Holocene activity. Alluvium is probably late-Tioga outwash, so a very early Holocene-age surface is indicated.
5(fig 3)	Central Bridgeport Valley fault zone	scarp in alluvium; t in alluvium	partly	latest Pleistocene to Holocene alluvium (Dohrenwend, 1982a)	N/A	E-facing scarp in soft, saturated alluvium partly modified by irrigation canal.
6(fig 3)	Eastern Bridgeport Valley fault zone	t in alluvium	partly	latest Pleistocene to Holocene alluvium (Dohrenwend, 1982a)	Holocene(?) floodplain deposits from East Walker River (Bryant this report; Dohrenwend, 1982a)	Tonal lineament in late Pleistocene to Holocene alluvium. South from this locality, flt. is generally not well defined, partly because of agricultural use and deposition along East Walker River.

Table 1 (to FER-155)
Tabulation of Observations

Locality #	Fault Name	Geomorphic feature delineating fault ¹	Fault well defined?	Youngest unit offset & source	Oldest unit not offset & source	Remarks ¹
7(fig 3)	Eastern Bridgeport Valley fault zone	scarp in alluvium possible cd; possible dov	Yes	latest Pleistocene to Holocene alluvium (Dohrenwend, 1982a)	N/A	Scarp profile: h = 4' to 5', $\angle = 100^\circ$, c=very rounded. This area saturated during field check in August 1983; in addition area used as grazing land by cattle; thus scarp would be rapidly degraded.
8(fig 3)	Bridgeport Reservoir fault zone	t in alluvium; scarp in older alluvium	Yes	Holocene alluvium (Dohrenwend, 1982a)	latest(?) Holocene lake deposits of Bridgeport Reservoir	Well-defined back-facing scarps offset older alluvium against alluvial fan deposits. Sharp tonal lineaments extend into youngest fan deposits.
9(fig 3)	Southern Bridgeport Valley fault zone	scarp in alluvium	Yes	Pleistocene outwash gravel (Dohrenwend, 1982a)	latest Pleistocene to Holocene alluvium (Dohrenwend, 1982a)	Scarp enhanced by stream erosion. Questionable fault origin except that west side is higher and therefore has been vertically offset.
10(fig 3)	Hunewill Hills fault zone	sharp t and scarp in alluvium; scarp and t in Tahoe moraine	partly	Holocene alluvium to northwest and Tahoe moraine to south (Dohrenwend, 1982a)	Holocene alluvium to south (Bryant, this report)	Discontinuous, short tonal lineaments along northwest trend principally delineated by tonal lineaments. Low east-facing scarp in Holocene alluvium north of Tahoe lateral moraine suggests Holocene activity.

Table 1 (to FER-155)
Tabulation of Observations

Locality #	Fault Name	Geomorphic feature delineating fault ¹	Fault well defined?	Youngest unit offset & source	Oldest unit not offset & source	Remarks ¹
11(fig 2)	Bridgeport Reservoir fault zone	linear cd; s; t	partly	Early Quaternary gravels (Dohrenwend, and Brem, 1982)	late Pleistocene to Holocene alluvium (Dohrenwend, 1982a)	With exception of broad, linear cd, fault is characterized by saddles and a tonal lineament where bedrock is faulted against early Quaternary gravels. Geomorphic features seem erosional, especially north of the linear cd, which may be due to landsliding.
12(fig 2)	Robinson Creek fault zone	aligned b;; arcuate escarpment escarpment	partly	Quaternary (Pleistocene) landslide deposits and early Pleistocene alluvium (Dohrenwend, 1982a; Dohrenwend and Brem, 1982)	Pleistocene alluvium (Dohrenwend and Brem, 1982)	These subparallel faults may be related to the large scale landsliding common along the northwestern margin of Bridgeport Valley.
13(fig 2,3)	Hunewill Hills fault	scarp in Sherwin glacial deposits, scarp(?) in alluvium	mostly	possible offset of Holocene alluvium (Dohrenwend, 1982a; Sherwin glacial deposits	N/A	Well-defined, NE-facing scarp in Holocene(?) alluvium, based on air photo interpretation by Bryant (this report). Scarp may have been formed by lateral stream erosion, but it is linear and aligns with NE-facing scarp in Sherwin glacial deposits to SE and well-defined E-facing scarp in Tertiary volcanic rocks to the north. Fault is a groundwater barrier, with run-off water accumulating in upthrown block.

Table 1 (to FER-155)
Tabulation of Observations

Locality #	Fault Name	Geomorphic feature delineating fault ¹	Fault well defined?	Youngest unit offset & source	Oldest unit not offset & source	Remarks ¹
MONO BASIN AREA						
14(fig 3)	Mono Lake fault	scarps in alluvial fans; beheaded talus cone	Yes	Paleozoic bedrock and late Pleistocene to Holocene alluvium (Dohrenwend, 1982a)	N/A	General E-facing escarpment in Paleozoic rocks. Holocene activity indicated by offset alluvial fans and beheaded talus cones. North of this locality fault less well defined.
15(fig 3)	Mono Lake fault	s and sb	partly	Paleozoic bedrock (Chesterman and Gray, 1975)	Sherwin till (Chesterman and Gray, 1975; Dohrenwend, 1982a)	Geomorphic evidence of recent (700,000yrs) faulting weak at this locality. Sherwin till not offset north of this location. Fault may be in Virginia Creek, but no specific geomorphic features observed.
16(fig 3)	Mono Lake fault	scarp in bedrock	partly	Paleozoic bedrock (Chesterman and Gray, 1975)	Holocene talus(?) (Bryant, this report)	Area has been modified by construction of penstock. Minor fault plane (jointing?) exposed in Paleozoic marble. Orientation: strike varies from N10°E to N10°W, dip 68°-70°E.

Table 1 (to FER-155)
Tabulation of Observations

Locality #	Fault Name	Geomorphic feature delineating fault ¹	Fault well defined?	Youngest unit offset & source	Oldest unit not offset & source	Remarks ¹
17(fig 3)	Mono Lake fault	scarp in lateral moraine	Yes	Tioga recessional moraines (Clark, et al., 1983)	modern stream deposits of Mill Creek (Bryant, this report)	Well-defined E-facing scarp offsets Tahoe lateral moraine and at least two recessional moraines that may be Tioga age (Clark, et al., 1983). Scarp profile in Tahoe moraine: h=60', λ =26° to 32°, c = 4'-5'. Scarp-slope is moderately armored with boulders.
18(fig 3)	Mono Lake fault	scarp and t in lake deposits	partly	Late Pleistocene and Holocene lake deposits (Kistler, 1966; Putnam, 1950; Dohrenwend, 1982a)	Holocene lake deposits (Kistler, 1966)	E-facing scarp near location 18 cuts across and vertically offsets (down to E) at least two lake terraces. Scarp profile in lake deposits: h \approx 15' to 20', λ = 26°. Slope of terraces above and below scarp is about 15°E. The height of the scarp is only approximate due to the acute angle at which scarp intersects lake terraces. In addition, 1 to 2 feet of snow covered ground during field check in Feb. 1984, making traverse of area and observation of soil development difficult to impossible. Exposure of well-cemented, coarse-grained calcareous lake deposits located about 500 feet north of this location. Bedding attitude

Table 1 (to FER-155)
Tabulation of Observations

Locality #	Fault Name	Geomorphic feature delineating fault ¹	Fault well defined?	Youngest unit offset & source	Oldest unit not offset & source	Remarks ¹
18(fig 3) (contd)						N35°W, 23°E. A tonal lineament cuts across additional terraces both north and south of this location. The E-facing scarp does not follow topography as would be expected with shoreline terraces. In addition, two springs occur along this relatively short segment. These springs, which are not common along the wave-cut terraces, also imply fault location.
19(fig 3)	Mono Lake fault	scarp; triangular facet; v.c.; "wine-glass" shaped drainage	partly	late Pleistocene to Holocene lake deposits? (Kistler, 1966)	N/A	Rapid lowering of lake level could account for "wine glass" shaped drainage, but the association with the triangular facet, which may truncate wave-cut terraces, implies recent faulting. Springs are also located along this scarp.

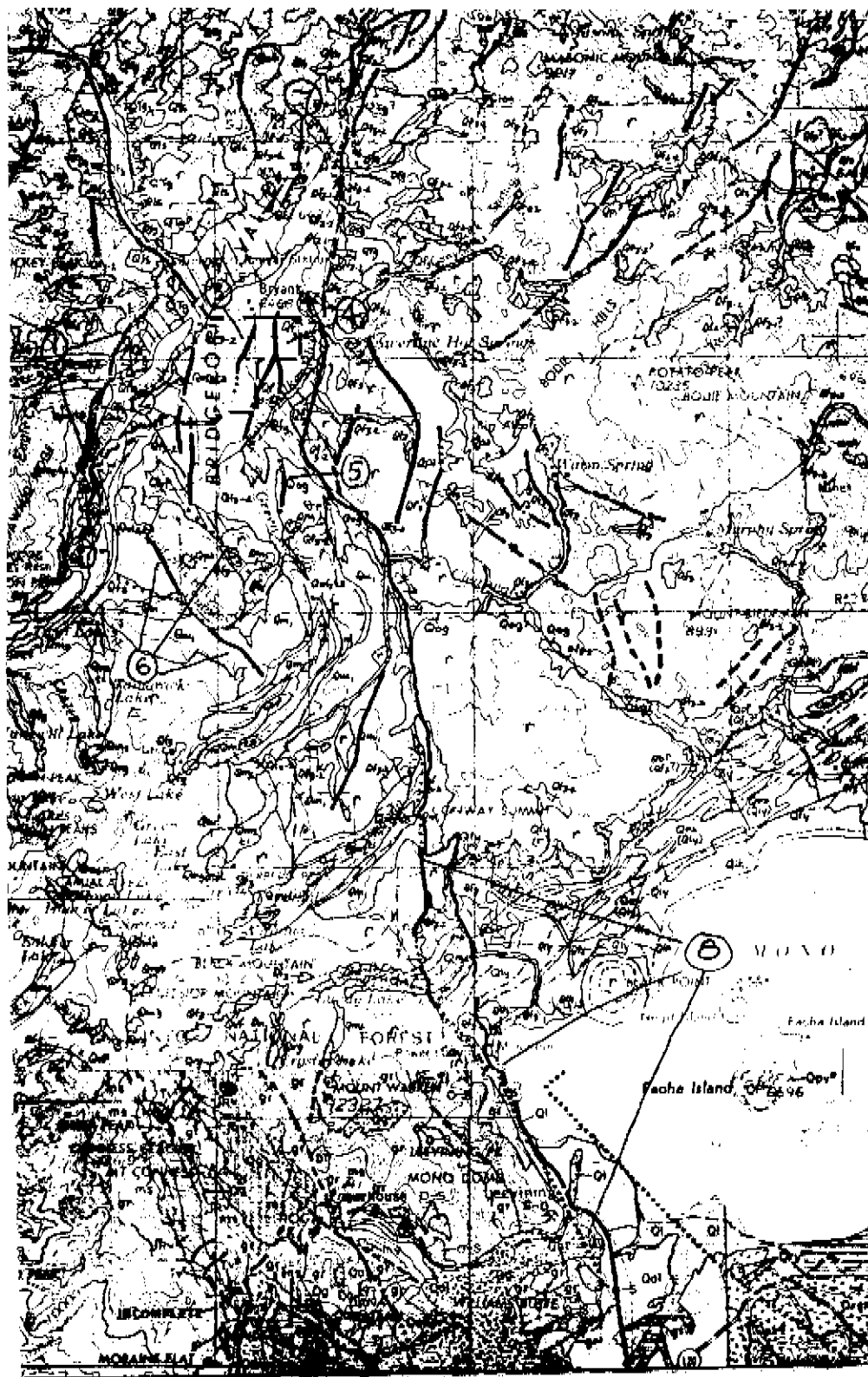
Table 1 (to FER-155)
Tabulation of Observations

not Locality #	Fault Name	Geomorphic feature delineating fault ¹	Fault well defined?	Youngest unit offset & source	Oldest unit offset & source	Remarks ¹
20(fig 3)	Mono Lake fault	scarp in alluvium	mostly	Holocene river terrace deposits of Lee Vining Crk. (Bryant, this report)	N/A	NE-facing scarp offsets stream terrace deposits of Lee Vining Crk. and, south of Tioga Pass Road, a wave-cut terrace of post-Tioga age (Putnam, 1950). Sense of offset is vertical, down to the E. Soil is poorly devel- oped or absent on stream terrace, indicating Holocene age. Scarp profile: $h=6'$, $\angle = 180^\circ$, $c \approx 4'$. North of Lee Vining Crk., fault deline- ated by t in alluvium, then fault merges with and paral- lels wave-cut terraces in Tahoe moraine.

TABLE 2 (to FER-155) - Fault Scarp Profiles

Bridgeport/Mono Basin

Fault Name/Location	Height	Angle	Crest Width	Material Offset	Fault Type
Eastern					
Bridgeport Valley Sec. 5, T4N, R25E	4'-5'	10°	Very rounded	Holocene(?) alluvium	Normal
Western					
Bridgeport Valley Sec. 12, T4N, R24E	8'	12°-15°	4'-5'	Holocene(?) alluvium	Normal
Robinson Creek Sec. 3, T4N, R24E	30'	20°	15'	Tahoe moraine	Normal
Robinson Creek Sec. 3, T4N, R24E	13'	22°	6'	Tioga outwash	Normal
Robinson Creek Sec. 3, T4N, R24E	110'+5'	24°-26°	NM	Tahoe (?) moraine	Normal
Robinson Creek Sec. 10, T4N, R24E	25'	22°	4'-5'	Tenaya (?) recessional moraine	Normal
Mono Lake Sec. 14, T2N, R25E	60'	26°-32°	4'-5'	Tioga recessional moraine	Normal
Mono Lake Sec. 14, T2N, R25E (same fault)	NM (> 80')	27°	NM	Tioga recessional moraine	Normal
Mono Lake Sec. 16, T1N, R26E	6'	18°	NM	Holocene terrace deposits	Normal
Mono Lake Sec. 16, T1N, R26E (same fault)	6'	12°	4'	Holocene terrace deposits	Normal



- ① Robinson Creek ft. z.
- ② Western Bridgeport Valley ft. z.
- ③ Central Bridgeport Valley ft. z.
- ④ Eastern Bridgeport Valley ft. z.
- ⑤ Southern Bridgeport Valley ft. z.
- ⑥ Hunewill Hills ft. z.
- ⑦ Bridgeport Reservoir ft. z.
- ⑧ Mono Lake ft. z.

Figure 1 (to FER-155). Location of faults in the Bridgeport Valley/Mono Basin study area. Base maps from Dohrenwend (1982) and Strand (1967), scale 1:250,000.

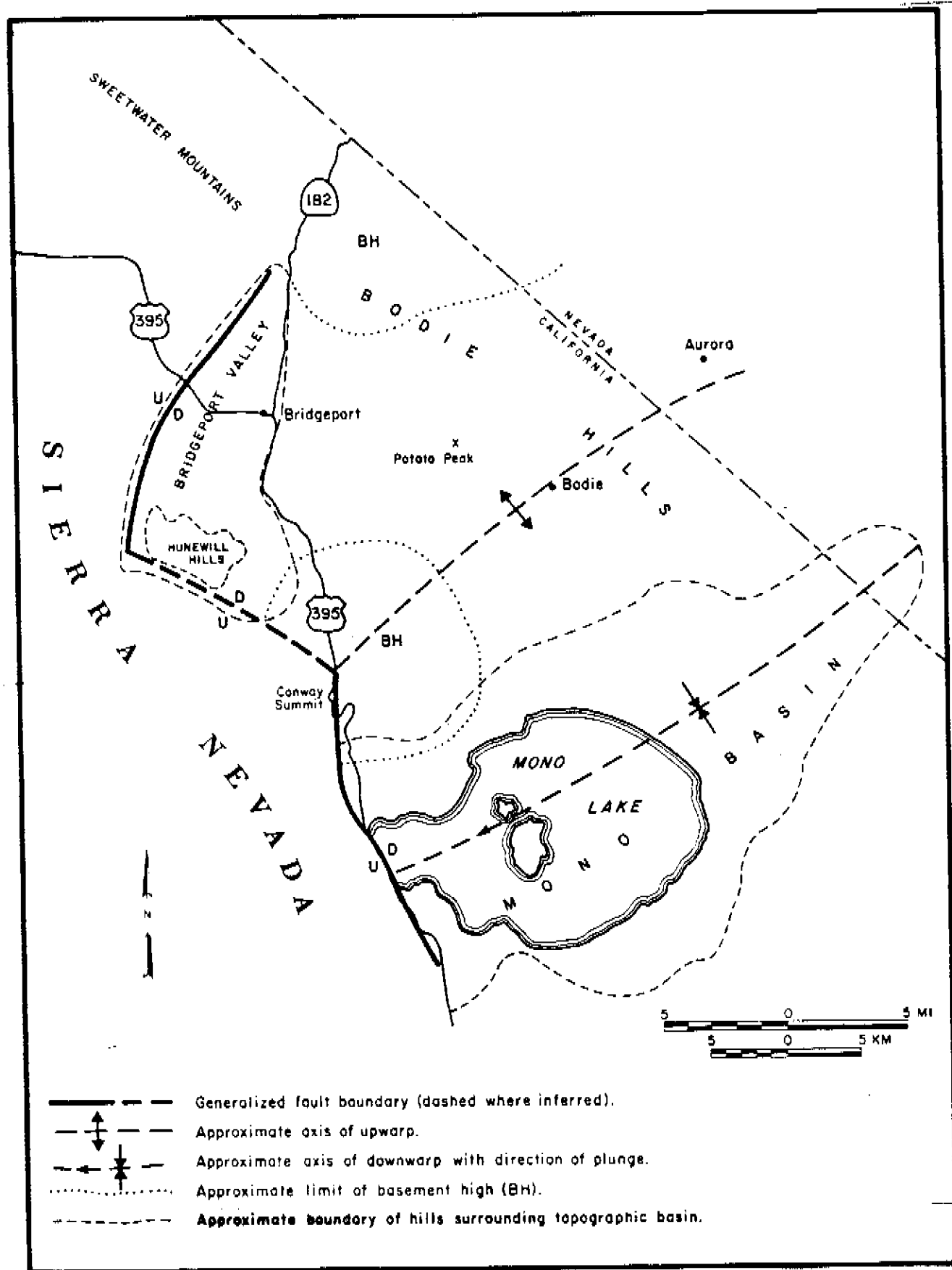


Figure 4 (to FER-155). Generalized regional structure of the Bridgeport Valley-Bodie Hills-Mono Basin area (from Higgins, et al., 1983).

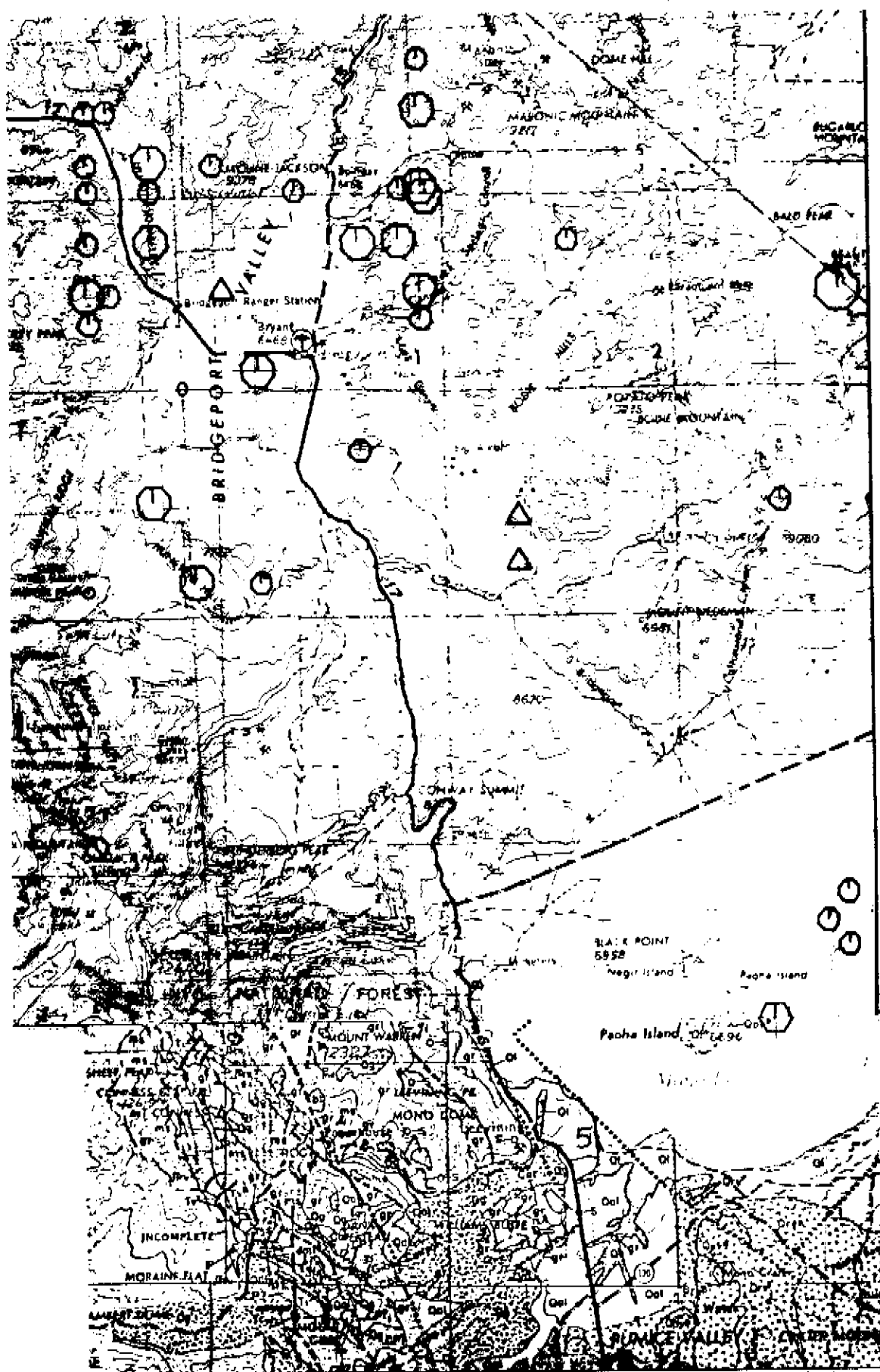


Figure 5 (to FER-155). Seismicity of the Bridgeport Valley/Mono Basin study area (1900-1974). Triangles are approximate locations of epicenters recorded by Westphal and Lange (1966). All others from Real, et al., 1978. Base map scale 1:250,000.